LA-UR-22-31819

Approved for public release; distribution is unlimited.

Title: FY 2022 Filter Test for TRU Waste Drum Prototype Unit

Author(s): Tao, Yong
Moore, Murray E.

Intended for: Report

Issued: 2022-11-08

FY 2022 Filter Test for TRU Waste Drum Prototype Unit

Yong Tao and Murray E. Moore

Objective

Continuing last year's (fiscal year 2021) work, a prototype instrument and an NPI-6 Integrated Work Document (IWD) were developed to assess the functionality of filters on transuranic waste containers (commonly called 55 Gallon ring-top drums) without requiring the removal of the drum lid. The purpose of this work is to determine the air flow and pressure characteristics associated with filter clogging, filter pressure drop at a fixed flow rate, and leakage around the lid seal.

The FY22 objectives included:

(A) Development of prototype device,
(B) Drafting an IWD document,
(C) Defining a filter clogging parameter,
(D) Assessing filter damage due to over-pressure events, and
(E) A path forward to obtain approval of the system safety filters in compliance with P101-16 Industrial Ventilation – non HVACR (LANL 2022).

Introduction

Thousands of transuranic (TRU) waste drums are currently used in the DOE complex. WIPP-approved filters are installed on TRU waste drum lids. These filters allow air and generated gases (hydrogen, etc.) and vapors to pass through a matrix of carbon or ceramic fibers. The filters are designed to trap radioactive aerosol particles that are entrained in the gas that passes from the interior of the container through the filter. The gas flow is driven by the pressure force of gases generated inside the containers and by pressure gradients due to atmospheric air pressure fluctuations.

Diagnosing the condition of drum filters is important to ensure worker and public safety and to determine the handling requirements of legacy waste drums. According to last year's test results, the pressure versus time curve across the filter at certain sampling flow rates can be used to assess the functionality of filters on waste drums without removal of the drum lid.

This document describes a Prototype unit, the draft IWD for system usage, a filter clogging parameter and a path forward to approve the prototype systems safety filters according to P101-16 Industrial Ventilation non-HVACR (LANL 2022).

Result 1. Development of prototype device

This FY22 prototype unit (Figure 1 and Table 1) was developed from a previous FY21 Proof-of-Concept (POC) unit (Tao and Moore 2021 and Brown et al 2014). For this fiscal year, an electric air pump (FPC101) replaced the hand pump (Mityvac™ MV8000) and Sensidyne Gilian GilAir Plus™ air sampling pump in the FY21 POC unit. A mass flow controller (FI101) was added to precisely control the sampling flow rate. A pressure gauge (PI101) was added to display the pressure of interface clamp (P103). A filter (FLT103) was added for worker safety. The P&ID Piping and Instrumentation Diagram (Figure 2) and P&ID item descriptions are given (Table 1).

<u>Features and limitations of the prototype</u>

(1) This prototype unit does not measure the aerosol collection efficiency of the drum filter.
(2) The pump (FPC101) and power supplies (E101 and E102) are in the lower section of the plastic case (Figure 1).
(3) The plastic tubing is color coded. Blue is for interface clamping; black is for pulling air (by vacuum) from the waste drum and white is a pressure tap to the pressure datalogger (PI102).

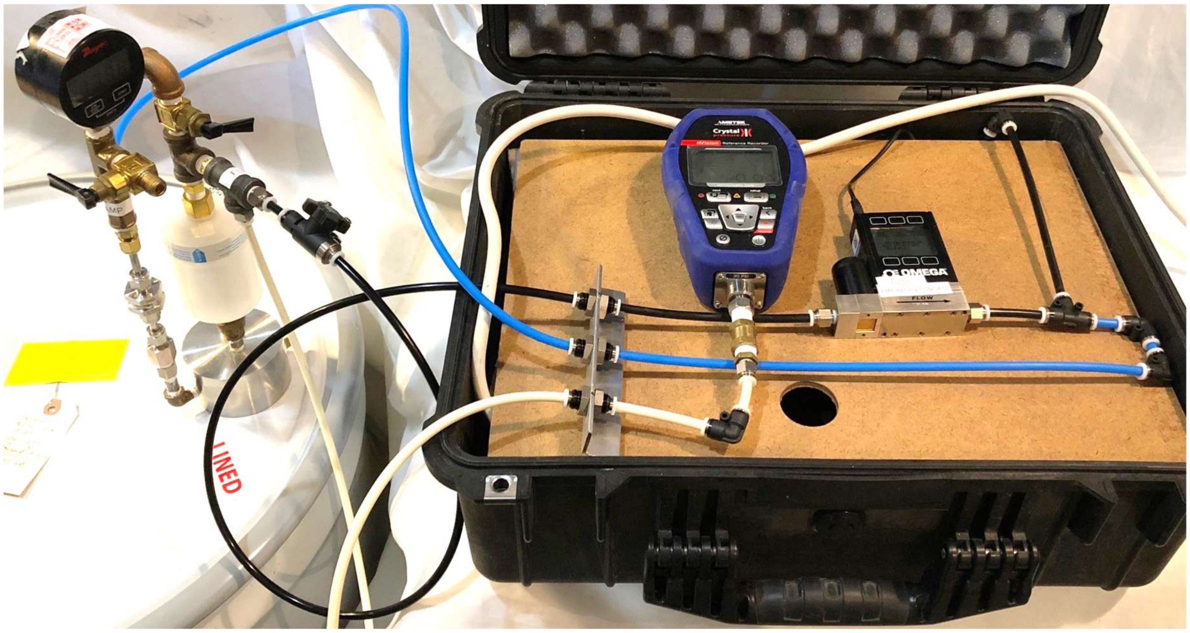

Figure 1. The FY22 prototype unit on an empty unused drum.

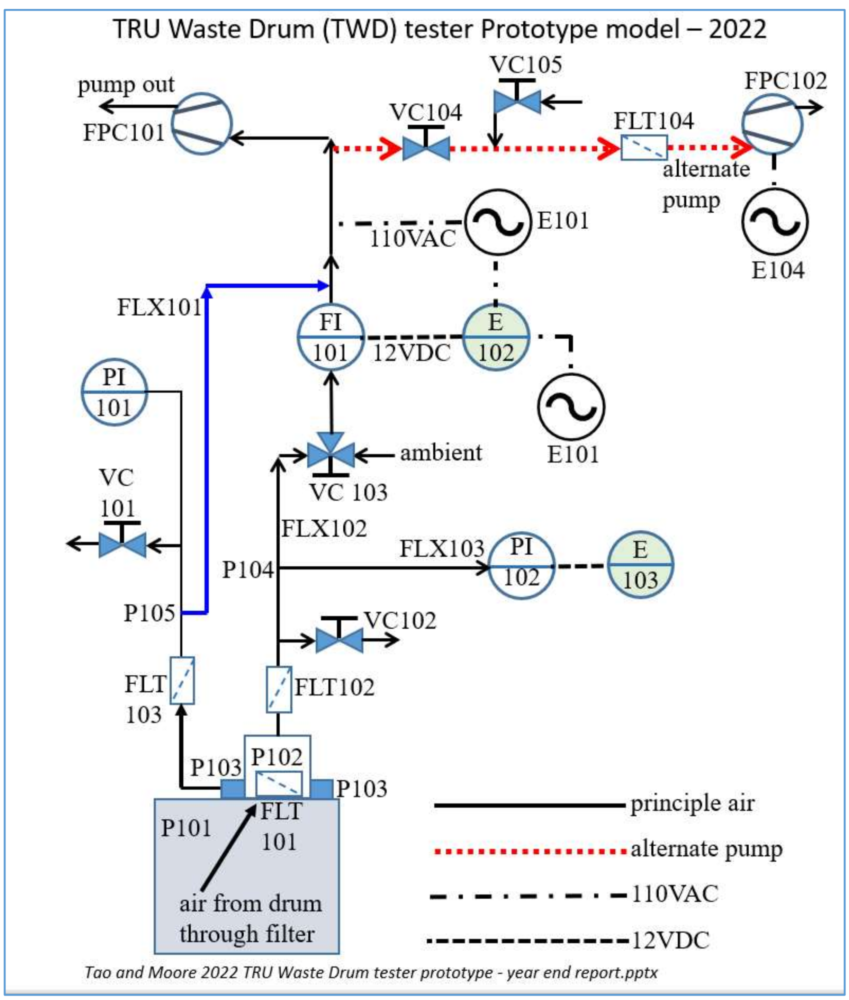

Figure 2. Process and Instrumentation Diagram P&ID of the FY22 Prototype unit.

Table 1. P&ID item description details

Item	Description
E101	Power supply for pump and E102 (110VAC)
E102	Power supply (12VDC adapter) for flow controller
E103	Power supply (battery) for pressure datalogger
E104	Power supply (110VAC) for alternate pump
FI101	Mass flow controller
FLT101	Drum filter (to be evaluated in drum P101)
FLT102	HEPA filter (Whatman™ model 2709T)
FLT103	Filter – Swagelok SS-4FWS-05; 0.5 micron
FLT104	HEPA filter (Whatman™ model 2709T)
FLX101	Flexline (blue) for annulus clamp from tee (P105) to manifold bracket
FLX102	Flexline (black) for flow controller from valve (VC103) to manifold bracket
FLX103	Flexline (white) for pressure data logger from tee (P104) to manifold bracket
FPC101	GTEK Micro-16 12VDC. Max 17.72 inHg vacuum; 16 LPM open air flow output.
FPC102	Gast model 1022-V103-GS7SX. Max 26 inHg vacuum; 263 LPM open air flow output.
P101	TRU waste drum with WIPP NFT filter (FLT 101) (NucFil-019D or NucFil-013).
P102	Adapter fits over the container filter with annulus P103 incorporated into its design
P103	Vacuum clamp is a coaxial annulus around the P102 adapter portion
P104	Port (tee) to measure the pressure downstream of filters FLT101 and FLT102
P105	Port (tee) to for the blue flexline from the clamp to the pump
PI101	Vacuum gauge indicator to monitor clamping effect on P103
PI102	Pressure recorder (Ametek Crystal nVision™, 30 psi module, model # CRY NV-30PSI)
VC101	Vent valve for zeroing the PI101 gauge
VC102	Vent valve for zeroing the PI102 gauge
VC103	Bypass valve for pump to measure drum vacuum.
VC104	Valve, control (B&K 1/2 brass)
VC105	Valve, control, bypass (B&K 1/2 brass)

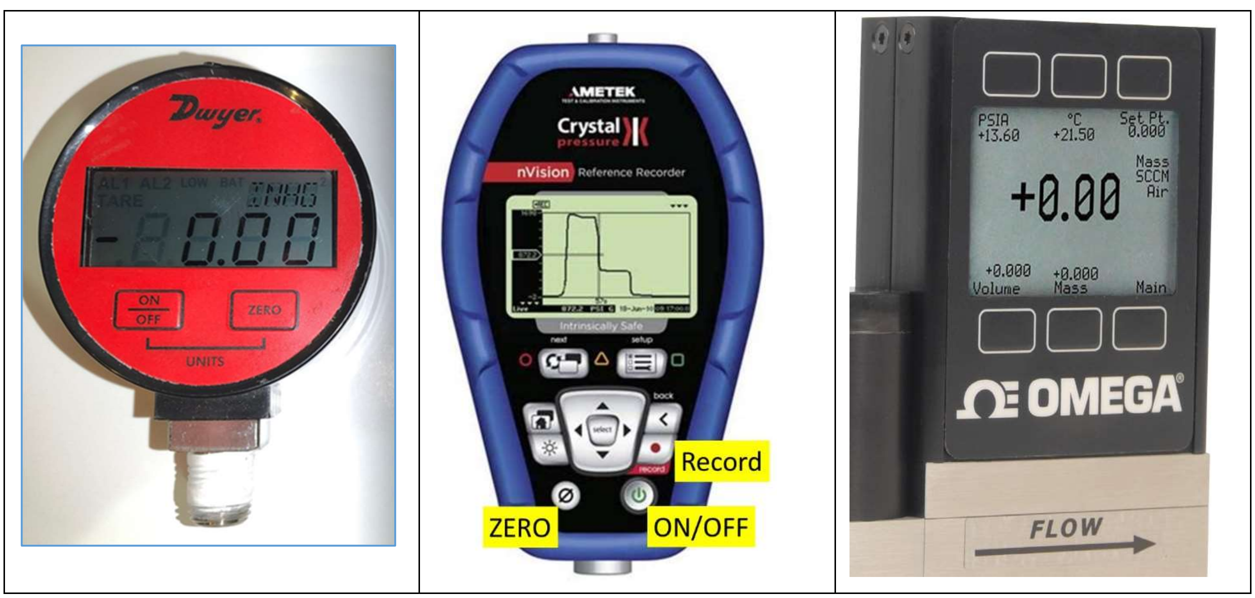

Figure 3. Examples of PI101 (inHg units), PI102 and FI101 (left to right).

Operation Sequences for Prototype TRU Waste Drum Filter tester (document in PA-IWD-01556, R0)

[1] Connect all devices and tubing according to the Piping and Instrumentation Diagram (P&ID) in Figure 2.

[2] Put the filter interface (i.e., P102 and P103) over the drum filter (FLT101) with the O-ring seal in contact with the top of the drum.

[3] Open VC101.

[4] Open VC102.

[5] Turn on PI101.

[6] Adjust display unit to "inHg" (inches of mercury).

[7] Zero pressure reading on the gauge.

[8] Close VC101.

[9] Turn VC103 to ambient side.

[10] Turn on the Ametek™ datalogger (PI102).

[11] Set up measurement parameters (i.e. sampling rate, file name, etc.) on the Ametek™ datalogger (PI102).

[12] Ensure zero pressure reading on the Ametek™ datalogger (PI102) before the measurement starts. Close VC102. Turn on "Record" for the Ametek datalogger (PI102). Name a "Tag" for a filename. A convenient format is "Tag1.10.21.2022", for example, to signify a tag dated on October 21, 2022. Other letter-based filenames are more cumbersome. After the tag is saved, the datalogger begins recording to that named data file.

[13] Turn on power supply E101.

[14] **NOTE** Pump (FPC101) draws a vacuum on the suction fitting (P103) and through the mass flow controller FI101 from the ambient side of valve VC103. The pressure gauge (PI101) needs to attain about (-13 inHg, depending on the pump operational capacity) to clamp the filter interface to the drum lid on top of the drum filter. The mass flow controller has two air flow rate display values, one for the setpoint of the flowrate, but another digital output displays the current operating flowrate through the controller.

[15] The mass flow controller (FI101) measurement unit is in "standard" flow units (e.g. SLPM). It needs to be converted to "ambient" units (e.g. ALPM) according to the ambient pressure and temperature of measurement where Qs(SLPM) = Qa(ALPM)*0.76(altitude correction factor for Los alamos). For example, at the Los Alamos altitude, 35 mL/min = 35 accm (ambient cubic centimeters per minute) = 0.035 ALPM = 0.026 SLPM (standard liters per minute).

[16] <u>WHEN</u> PI101 reaches about -13 inHg,
<u>THEN</u> turn valve (VC103) to connect the pump (FPC101) to the (P104) fitting to pull air out of the drum interface (P102) and through the drum filter FLT101.

[17] <u>WHEN</u> the measured pressure reaches a pre-determined value decided by the experimenter,
<u>OR</u> when a pre-set time (e.g., 30 seconds) has elapsed,
<u>THEN</u> turn valve (VC103) to ambient side.

[18] **NOTE** If measuring the drum leakage, valves (VC101 and VC102) must remain closed.

[19] (optional) <u>IF</u> measuring the drum leakage,
<u>OR</u> at SME discretion,
<u>THEN</u> keep the datalogger (PI102) running for pre-determined time decided by the experimenter.

[20] Turn off E101.

[21] Stop the datalogger (PI102).

[22] Turn VC102 to release pressure in the drum interface P102 and the drum P101.

[23] Turn VC101 to release pressure in the drum interface P103.

Result 2. Drafting an IWD document

Tao, Yong. 2022. Prototype Filter Test for TRU Waste Drums. Los Alamos National Laboratory document number PA-IWD-01556, R0.

Result 3. Defining a filter clogging parameter

At a fixed sampling flow rate, the measured pressure drop increases with the amount of filter clogging. In this proposed definition, a filter would be clogged if it allowed an essentially zero flowrate for a defined system-pump configuration.

<u>Operational experimental parameters</u>

In FY2022, tests were done to define the system operational parameters. These tests should be performed for TWD measurements as part of the operating procedure.

(1) Measure the force (i.e. vacuum) on the clamp (P102 and P103) available from the system pump. This measurement can also determine the ability of the TWD clamp to create and maintain a leak-tight seal on a Hagan container or a 55-gallon drum lid. A Hagan container lid with filter (NucFil-013 LANL-659) with a mass of 1770 g was used as a test item. In this case, if the TWD clamp (P102 and P103) could lift the edge of the Hagan lid about an inch above a horizontal orientation and maintain the seal for 20 seconds, it was considered to successfully hold the seal. For five replicate tests at a clamping vacuum of -12.7±2.9 inHg, the TWD adapter clamp held the test Hagan lid for 20 seconds, while at a clamping vacuum of -7.8±2.0 inHg, the adapter failed to hold the Hagan lid. For future test situations, this test should be repeated to establish the operating capabilities of the available system configuration. This anticipates possible system modifications due to repairs or component substitutions.

    At the end of FY2022, the selected system pump (GTEK Micro16) failed during operational testing and final experimental steps were conducted with a Gast model (1022-V103-GS7SX SN 1079) pump. Both pumps deliver a similar amount of vacuum (inHg) capability, but the GTEK system is a small (16 LPM air flow capacity) portable 12VDC system, whereas the Gast system is a much larger (263 LPM air flow capacity) 110VAC device. The GTEK pump failed during tests to mimic a clogged filter condition. It is recommended that any future system should include a safety device to prevent any possible condition overload that could damage a small portable pump.

(2) Measure the system pump capability for a hypothetical clogged filter. The system pump vacuum needs to be measured for a dummy clogged filter situation. For this example, a Hagan container lid with its filter was tested, with the underside of the filter surface sealed with PVC adhesive tape.

(3) The vacuum-seal of the TWD clamp was measured on a Hagan container and a 55-gallon drum. The stainless-steel interface (P102 and P103) was compressed (by hand) to create improve the vacuum seal. If the measured filter pressure drop (on the PI102 pressure gauge datalogger) changed after the downward force was released, then this information was noted and recorded. In Table 2, the vacuum seal would be stable at about -12 inHg to -13 inHg, consistent with the Hagan lid lift test.

Table 2. Tests to assess the effect of clamping vacuum (inHg) on measured pressure drop

Tests to assess the effect of clamping vacuum (inHg) on measured pressure drop	Clamp vacuum (inHg)	Was the TWD adapter manual compressed (by the operator) for 10 seconds onto the container surface?	Change of the measured pressure drop downstream of the tested filter (inWC) with summary statement	Time interval, min	Test index
Initial clamp vacuum (inHg)	-12.4	yes	-0.15 to -0.15	2	1
Final clamp vacuum (inHg)	-12.4		(maintained seal)		
Initial clamp vacuum (inHg)	-12.4	no	-0.15 to -0.15	1	2
Final clamp vacuum (inHg)	-12.4		(maintained seal)		
Initial clamp vacuum (inHg)	-12.4	yes	-0.15 to -0.15	5	3
Final clamp vacuum (inHg)	-12.4		(maintained seal)		
Initial clamp vacuum (inHg)	-12.4	no	-0.15 to -0.79	1	4
Final clamp vacuum (inHg)	-9.2		(seal failed)		
Initial clamp vacuum (inHg)	-9.2	yes	-0.15 to -0.60	1	5
Final clamp vacuum (inHg)	-9.2		(seal failed)		
Initial clamp vacuum (inHg)	-9.2	yes	-0.15 to -0.37	1	6
Final clamp vacuum (inHg)	-9.2		(seal failed)		
Initial clamp vacuum (inHg)	-9.2	yes	-0.15 to -0.23	1	7
Final clamp vacuum (inHg)	-9.2		(seal failed)		
Initial clamp vacuum (inHg)	-9.2	yes	-0.15 to -0.53	1	8
Final clamp vacuum (inHg)	-9.2		(seal failed)		
Initial clamp vacuum (inHg)	-9.2	no	-0.53 to -0.15	1	9
Final clamp vacuum (inHg)	-12.5		(self-sealed)		
Initial clamp vacuum (inHg)	-12.5	no	-0.15 to -0.15	3	10
Final clamp vacuum (inHg)	-12.5		(maintained seal)		
Initial clamp vacuum (inHg)	-12.5	no	-0.15 to -0.29	1	11
Final clamp vacuum (inHg)	-9.1		(seal failed)		
Initial clamp vacuum (inHg)	-9.1	no	-0.29 to -0.45	2	12
Final clamp vacuum (inHg)	-9.1		(seal fail continued)		
Initial clamp vacuum (inHg)	-9.1	no	-0.45 to -0.15	1	13
Final clamp vacuum (inHg)	-12.5		(self-sealed)		
Initial clamp vacuum (inHg)	-12.3	no	-0.15 to -0.15	5	13
Final clamp vacuum (inHg)	-12.3		(maintained seal)		
Tao and Moore 2022 TRU Waste Drum tester prototype - year end report.xlsx					

(4) The vacuum on the clamp (P102 and P103) is dependent on the system pump (Figure 4). The performance curve (from the 110VAC Gast pump) is similar to previous operating conditions observed (from the 12VDC GTEK pump). The test condition starts at the flow controller setpoint of 0.026 SLPM, and a 0.0 inWC pressure drop

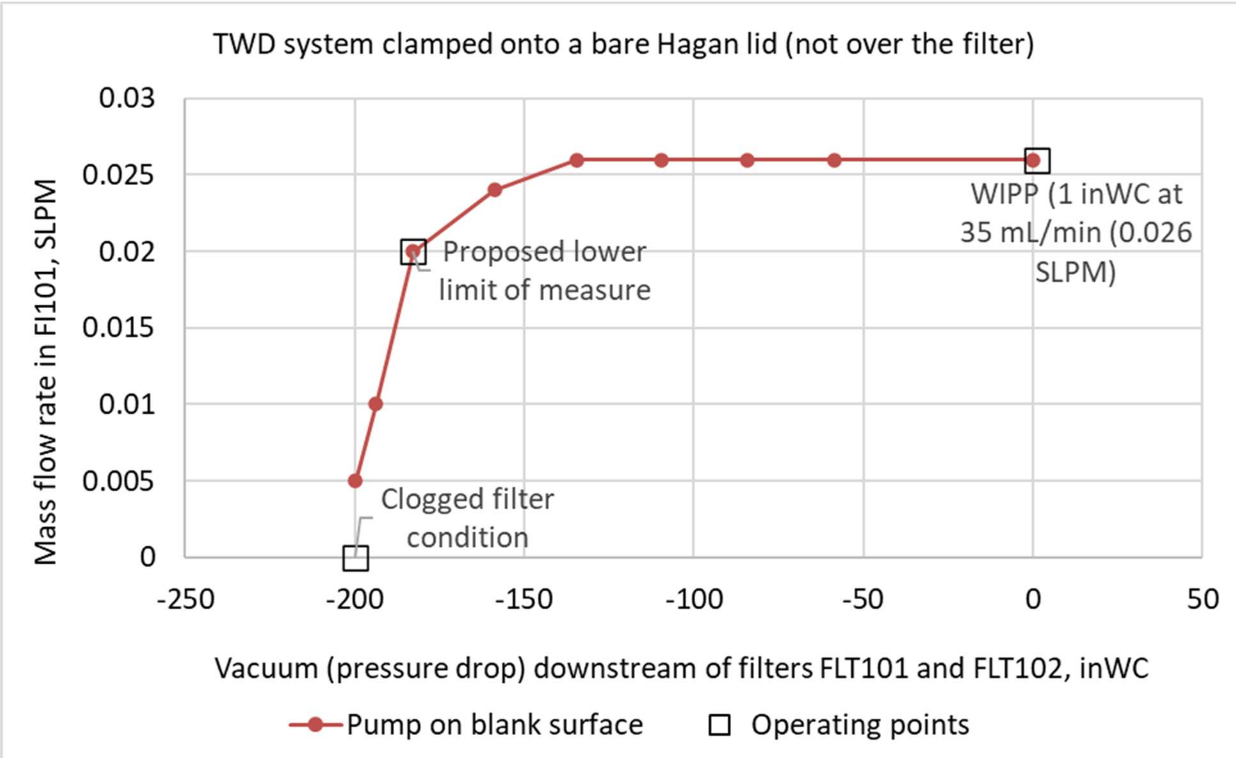

Figure 4. The mass controller (FI101) air flow rate approaches a zero-flow condition under simulated clogged conditions.

Because the smaller GTEK 12VDC pump was damaged during a simulated clogged filter test, it is not recommended to repeat this test condition. Instead, the clogged filter condition should be defined as a zero-flowrate condition at the observed maximum experimental vacuum that is available from the pump. The maximum experimental vacuum is the value of the vacuum on the adapter annulus (i.e. the reading from the PI101 pressure gauge).

During the test in Figure 4, about 5 minutes of time was required for the filter pressure drop to increase from about -1 inWC to -192 inWC. This was performed with a steady-state draw from the pump onto the (P102 and P103) adapter, and it indicates the amount of time required for a flowrate of 0.026 SLPM to create a deep vacuum on the adapter seal. Although this time period is slow enough for an operator to notice the increase in pressure drop (i.e. a decrease in vacuum), it is recommended that a vacuum relief valve should be installed to prevent future damage to any system pump devices.

(5) Figure 5 indicates the measured system pump capability for a hypothetical clogged filter. For this example, a Hagan container lid with its filter was tested, but with the underside of the filter surface sealed with PVC adhesive tape. Note the shape and outcome of this graph is similar to Figure 4. The total number of data points for the air flowrate through the mass flow controller could be increased if it were equipped with a datalogging capability. A 100% clogged filter would have a zero measured flowrate at a vacuum (negative pressure drop) of -200 inWC.

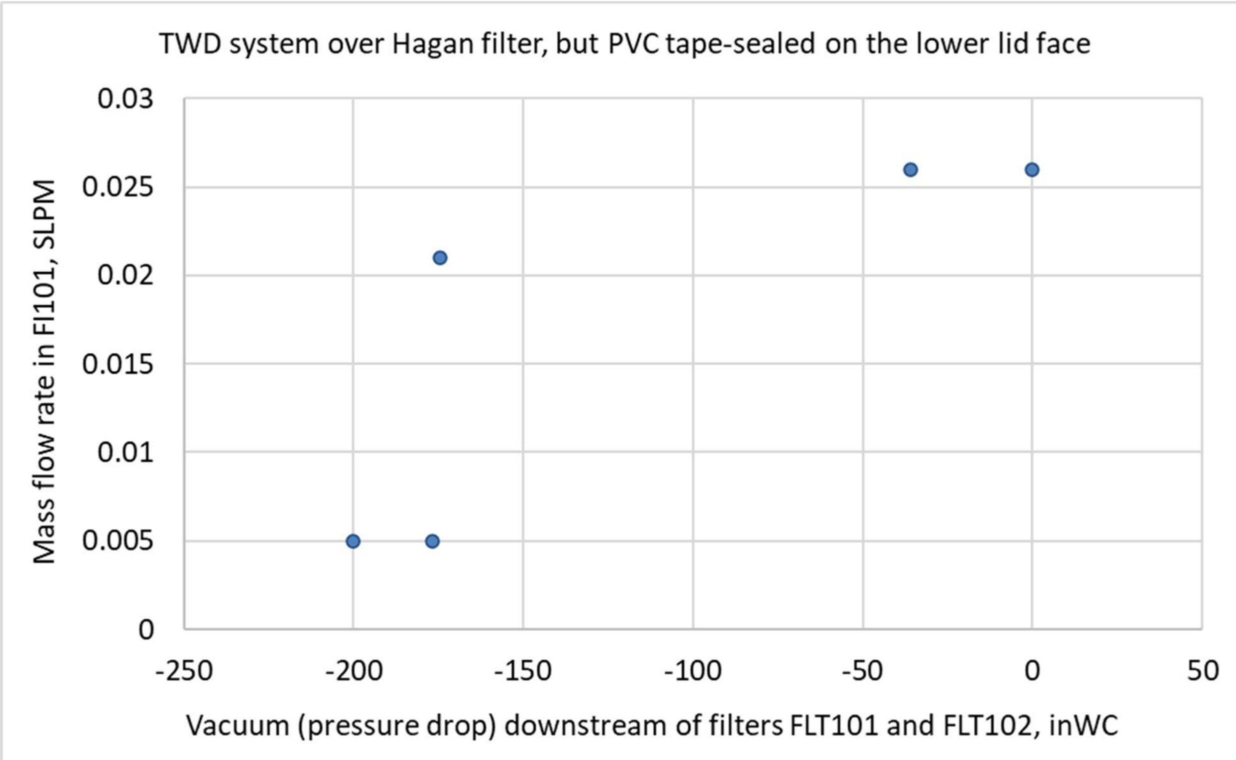

Figure 5. The TWD system evaluated a Hagan lid and filter with a PVC-tape sealed closure.

During system operation, to prevent possible damage to the small portable 12VDC pump, it is recommended to prevent (i.e. stop) the operation of the pump at (or before) the point that the filter air flow rate decreases to 0.02 SLPM (as indicated on the digital output of the mass flow controller).

Filter permeability coefficient

The flow of air through an air filter is a viscous flow phenomenon with a linear relationship between pressure drop and filter face velocity (Darcy 1856),

$$\Delta P = \frac{V\,\mu}{B} \tag{Eq 1}$$

where
ΔP = pressure drop across the filter,
μ = air viscosity, and,
B = permeability coefficient for an individual air filter (Stern et al 1960).

For the air flowrate, Q, through a circular filter of diameter, D, the filter face air velocity, V, is:

$$V = \frac{4\text{Q}}{\pi\, D^2} \tag{Eq 2}$$

and therefore the filter pressure drop is

$$\Delta P = \left(\frac{4\,\mu}{\pi\, D^2 B}\right) Q \tag{Eq 3}$$

At a given test air flowrate, if a filter begins to clog with collected material, its permeability coefficient, B, would decrease, and its pressure drop would increase. The necessary data (Figure 8) to calculate B, the permeability coefficient (Stern et al 1960) of a drum filter was gathered. The steady-state pressure drop downstream of a drum filter (FLT101) and the system safety filter (FLT102) was measured for five different air flowrate values (35, 70, 100, 130 and 200 accm). From equation 6, the value of B is the slope of the line of flowrate (Q) compared to filter pressure drop (P) for two different endpoints of the line 1 and 2, where B = ($\Delta Q/\Delta P$).

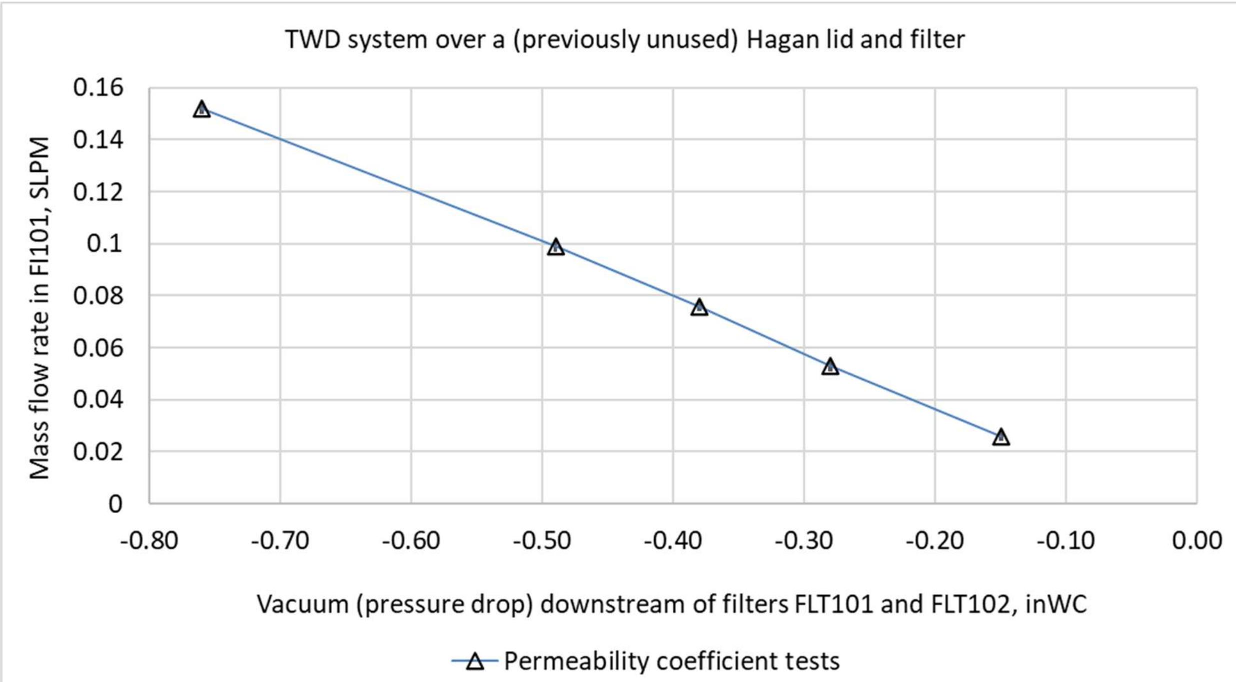

Figure 6. Test data to calculate B, the filter permeability coefficient.

Result 4. (Assessing filter damage due to over-pressure events)

During the measurements with the TWD (TRU Waste Drum) Tester, the drum filter will be subject to a vacuum up to -13 inHg. During review of the IWD document, a concern developed of whether the drum filter media would remain intact during these tests. In a previous LANL experimental study (Moore and Davis 2020) it was shown the drum filter media remains intact after repeated 30-psig pressurization (i.e. pulses of 1-second duration that included 100 g challenges of (1 µm particle diameter) cerium oxide test powder). Since the vacuum pump induces a gradually-ramped pressure difference of about -13 inHg (6.4 psi) across the filter, it is assumed that the drum filter media will not be damaged during the test with a -13 inHg vacuum.

Result 5. (System safety filter approval in compliance with LANL P101-16 (Industrial Ventilation – non HVACR).

In September 2022, meetings were held with Michael Rosenow (LANL OSH-ISH: Industrial Safety & Hygiene) to discuss the possible experimental validation of the TRU Waste Drum Filter tester.

At this point in time, the defined path forward includes:

(1) Perform testing of the complete TWD tester. That is, the system will not be disassembled for the tests, since the device must demonstrate a minimum of leakage of aerosol under test conditions (Moore et al 2011).
(2) Utilize existing experimental facilities in the LANL (Radiation Protection Services group) Aerosol Engineering Facility at TA-03-0130. This includes an aerosol wind tunnel (US EPA 2016) that can generate and measure analytical test aerosol.
(3) LANL staff member Michael Rosenow has the signature authority to approve the qualification testing that would occur in the Aerosol Engineering Facility for this purpose.

Conclusions and Recommendations for Future Work

This FY22 prototype unit (Figure 1) was developed from a previous FY21 Proof-of-Concept (POC) unit. A LANL group NPI-6 (Plutonium Capability Transuranic Waste Management) IWD was developed (PA-IWD-01556) to execute the test at TA-55. A method is given to define 100% clogged filter. The safety of the filter under test conditions was discussed.

This FY22 prototype unit could be deployed after validation of the safety filters (FLT102 and FLT103) in their integrated system configuration according to P101-16 Industrial Ventilation – non HVACR (LANL 2022). The Aerosol Engineering Facility at the Los Alamos National Laboratory has the capability to do the filter verification, according to an RLM manager-level walkdown from LANL IH specialist Michael Rosenow.

It is recommended to establish a data logging capability for the vacuum gauge on the adapter clamp PI101 and on the mass flow controller FI101 (SLPM units).

It is also recommended that any future system should include a vacuum relief valve (in between P102 and FLT102) to prevent any possible overload that could damage a small portable pump.
A series of intentionally clogged test filters could be created with varying amounts of collected test aerosol. This spectrum test filters with different clogged percentages could be used to scope the system operation for future measurements.

References

Brown AD, Runnels JT, Moore ME, Reeves K. LAUR-14-27446 Final Report: WAS Project No.: 2013-HS-2013008: I. In-Place Filter Testing Instrument for Nuclear Material Containers II. Canister Filter Test Standards for Aerosol Leak Rates. Los Alamos National Laboratory, 2014.

Darcy H. Les fontaines publiques de la ville de Dijon: exposition et application. Victor Dalmont; 1856.

LANL 2022. P101-16. Industrial Ventilation (non-HVACR). Rev 3. Los Alamos National Laboratory, Los Alamos NM.

Moore ME and Davis JT. 2020. LA-UR-20-29590. Pressurizing Hagan and SAVY containers to 30-psig (air) to measure the release of analytical cerium oxide test powder. Los Alamos National Laboratory, Los Alamos NM, 2020.

Moore ME, Smith PH, Veirs DK, Anderson LL, Klemm R, 2011. Low Flow Filter Efficiency Testing, Los Alamos National Laboratory, Los Alamos Unclassified Report LA-UR-11-10891, 2011

Stern SC, Zeller HW and Schekman AI. 1960. The aerosol efficiency and pressure drop of a fibrous filter at reduced pressures. J Colloid Sci. 15(6), 546-562, 1960.

Tao, Yong. 2022. Prototype Filter Test for TRU Waste Drums. Los Alamos National Laboratory document number PA-IWD-01556, R0.

Tao Y and Moore ME. 2021. LA-UR-21-30212. FY 2021 Filter Test for TRU Waste Drum POC Proof-of-Concept Unit. LA-UR-21-30212. Los Alamos National Laboratory, Los Alamos NM, 2021.

US DOE 2022. Department of Energy. CH-TRAMPAC. Contact-Handled Transuranic Waste Authorized Methods for Payload Control. Revision 6. 2022

US EPA 2016. Environmental Protection Agency 40 CFR 53:42 Ambient air monitoring reference and equivalent methods, generation of test atmospheres for wind tunnel tests, 2016.

US NRC 2011. US Nuclear Regulatory Commission. Remote-Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC), Rev. 1, February 2011.

APPENDIX

(1) Metadata file locations

Description	Path and filename	Logbook and location
Report file	"\\dcstorage.lanl.gov\eshq_rp_2\Aerosol Engineering\Waste drum - Tao 2020\Tao and Moore 2022 (draft) TRU Waste Drum tester prototype - 2022 report - year end.docx"	N/A
P&ID legend in Excel	"\\dcstorage.lanl.gov\eshq_rp_2\Aerosol Engineering\Waste drum - Tao 2020\Tao and Moore 2022 TRU Waste Drum tester prototype - year end report.xlsx"	N/A
Pressure datalogger	"\\dcstorage.lanl.gov\eshq_rp_2\Aerosol Engineering\Waste drum - Tao 2020\Pressure data Ametek\Tag 1.10.14.2022 Actual time.xlsx"	Logbook Moore-Waste-drum-2020-1 page 71-74